

# **GRAVENSTEIN APPLE STORAGE TESTS**

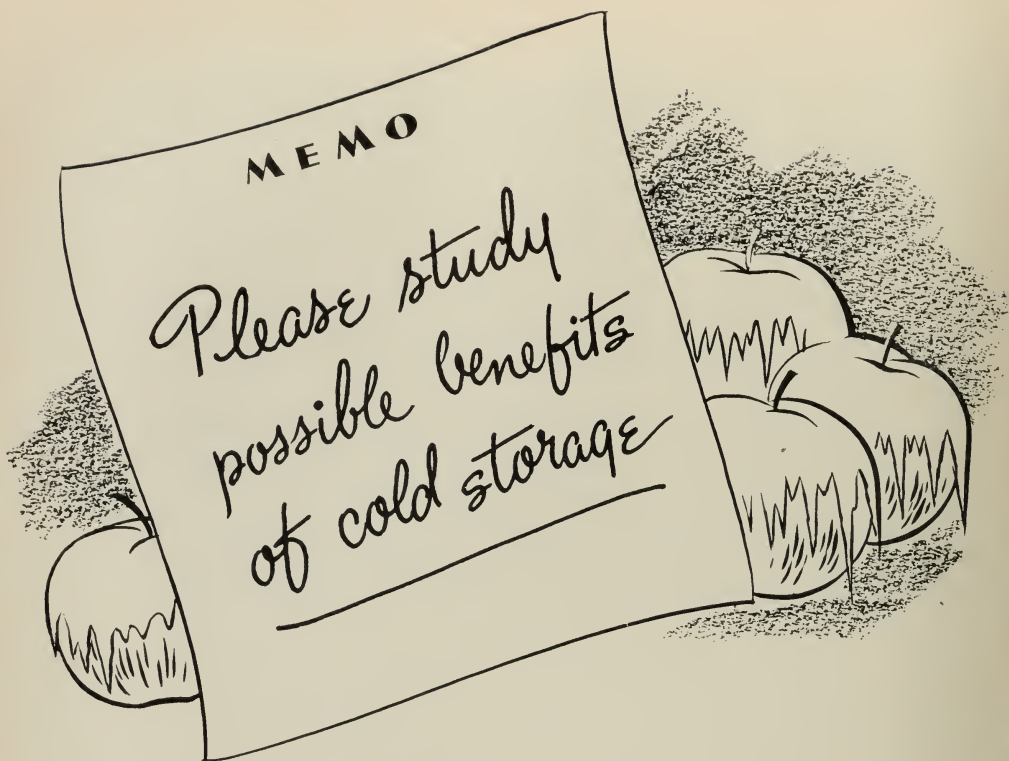
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### ***This Bulletin***

describes experiments made on Gravenstein apples in an attempt to lengthen their marketable life.

The apples were placed in cold storage for a period of about 4 months and changes that would affect their market value were checked and recorded periodically. Some of the apples were subjected to further tests to determine their shipping possibilities and their value for processing.

### ***The Findings***

although not conclusive on all points, indicate the advantages of cold storage in prolonging the marketable life of Gravensteins. Factors limiting the storage life of this variety are discussed.

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**The problem was . . .**

how to lengthen the salable life of Gravenstein apples. Gravenstein growers felt that the relatively short period during which their fruit could be sold, either as fresh fruit or for processing, was a serious handicap. For the most part, they had to sell as the fruit was harvested, or take a loss from spoilage.

**And so . . .**

a group of growers asked the University of California to conduct some tests to determine to what extent cold storage would solve the problem.

**Tests were made**

on 200 boxes of Gravensteins from Sonoma County. The apples were stored at 32° F for periods ranging up to 120 days. A few of the apples were given artificial atmospheres (under laboratory conditions).

After 2 months' storage period, some of the apples were subjected to simulated shipping conditions of 10 to 12 days duration. At this time, and also later, other lots of apples were made into sauce which was tested and graded.

Details of the testing methods and of the findings start on page 5.

**These were the findings**

Cold storage will help to lengthen the salable life of Gravensteins, but there are certain limiting factors involved, chief among which are:

1. Bitter pit, which may develop within a few weeks after storage.

2. Scald.

3. Deterioration in flavor, which develops after 2½ to 3 months.

4. Overripeness and breakdown in the flesh, which takes place after 100 to 120 days.

These troubles were not always definitely correlated in the fruit from any one orchard, but in general this appeared to be the case. Apples from 2 or 3 of the

orchards developing the highest percentage of bitter pit also showed the most scald and breakdown. Conversely, 3 orchards showing little bitter pit development were low in the other troubles.

Fruit from different orchards seemed to have inherent differences in keeping quality. These differences may have been due to variations in cultural practices by growers, but this phase was not studied in the tests. The primary influencing factors which were studied were:

1. Maturity of fruit at harvest.

2. The time interval between picking and storing.

3. The length of the storage period.

4. Size and color of fruit.

**Time of picking**

The most desirable fruit for storage purposes was fruit harvested at midseason. Fruit harvested late in the season and stored without delay was next most desirable. But fruit picked early in the season should not be stored for future use.

**Size of fruit**

Large sized fruit developed more bitter pit and breakdown than smaller fruit and had inferior storage qualities. Little difference was found in the keeping quality of small and medium sized fruit.

**Disorders**

**Bitter pit** was most prevalent in early harvested and in large sized apples.

**Scald** was worse on early picked fruit. Highly colored apples—those with red stripes—were less susceptible to scald than green fruit.

**Breakdown** was associated with large fruit, delay in cooling, and late picking.

**Storage possibilities**

**For the fresh market**, apples should be removed from storage sufficiently early to be sold while still sound and attractive.

For the California market this means they should not be held over 2 or 3 months; for the eastern market, they should not be held longer than 2 months.

**For processing**—where the fruit is used immediately after being taken from storage, and where appearance and a slight amount of bitter pit is not important—some Gravensteins may be stored up to 4 months.

The tests showed, however, that fruit from some orchards should not be held longer than half of the above periods.

Sauce made from Gravensteins stored for 2 to 4 months or more, while not considered equal in quality to that made from fresh apples, was nevertheless considered of standard grade—the quality of

most sauce made in the district from which the apples were taken.

Apples showing scald, and considerable bitter pit, if not too deep seated, may be acceptable for processing into applesauce.

### **Artificial atmosphere tests**

Preliminary results from storing Gravensteins in artificial atmospheres, under laboratory conditions, indicate that color and softening may be materially retarded, and that storage life may be extended 50 per cent or more. The artificial atmospheres, however, did not retard flavor deterioration. Both aroma and flavor appear to be lost as quickly, or even more quickly than is the case when the fruit is stored in normal air.

### **Acknowledgments**

For their assistance or contributions to the investigations described here, the authors wish to extend their appreciation to the following:

Growers who donated the necessary fruit—Leland Barlow, Batten Bros., W. W. Blackney, David M. Durst, Alfred Hallberg, W. W. Hastings, D. Guy Hutchinson, D. Morengo, Noldeke Bros.

Denham and Tom Barlow, who provided storage space and processed some of the fruit.

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## ***And here is the whole story***

The period of marketing and/or utilization of Gravenstein apples has been relatively short, when compared with that of later-ripening varieties. Eastern shipments have not always continued throughout the harvest period and fruit for the local fresh market and for processing has (with few exceptions) been available only during the harvesting period, and for such time thereafter as it could be main-

tained in marketable condition under ordinary summer temperatures.

It was felt that this relatively short period during which the fruit remained marketable was a serious handicap to growers of Gravensteins and severely limited their sales. It was a case of selling all of their apples within a few weeks after harvest, or having to take losses from spoilage.

## ***The problem was this . . .***

What are the possibilities of extending the marketing period of Gravenstein apples by the use of cold storage? If the apples were cold stored for a period of time could they then successfully compete with later-ripening varieties either on local or eastern fresh fruit markets?

If held for an extended period, what would happen to the quality of the fruit? Would it still be more desirable for sauce

purposes than most other later varieties? With these questions in mind, a group of growers at the 1949 meeting of the Sonoma County Planning Conference requested the University of California to undertake an investigation and try to arrive at the answers. The investigation was made, and this report presents an outline of the methods used and the results obtained.

## ***This is what was done . . .***

**Representative samples were taken from orchards over most of the harvesting period.**

In attempting to answer the question "How long may Gravenstein apples be held in cold storage?" other questions suggested themselves:

What variations in keeping quality may be expected in fruit from different orchards? What will be the influence of different times of picking; different sizes of fruit; a lag in time intervals between picking and storing? What will be the life of the fresh fruit after storage, or

the quality of the processed product made from stored apples?

The program was organized to secure information on all of these points—to get rather general information on storage possibilities rather than to make an exhaustive study of any single phase of the problem.

**Selection of orchards.** Recognizing the variability in fertilizer practices and in the vigor of trees in different orchards, and how this variability might be reflected in storage quality of the fruit, apples were secured from 9 orchards selected as being representative of the Sebastopol district. In location, the orchards extended from 5 miles south of

TABLE 1: EXPERIMENTAL ORCHARDS—GRAVENSTEIN COLD STORAGE TESTS—1949

Orchard No.	District Site	Soil*	Fertilization Recent Years	Trees			Fruit	
				Size	Vigor	Crop	Size	Striping†
1	Jonive high ridge	Gold Ridge f.s.l. over sandstone	None	large	rather low	large, 15 bx. per tree	S to M	18%
2	Sebastopol level ground	Sebastopol gr.s.l. over clay	None	small (orch.open)	low	moderate	mostly small	25%
3	Cunningham N. slope—low ridge	Cotati s.l. over clay	None since 1945	small (orchard open)	rather low	light, approx. 5 bx. per tree	S to M	45%
4	Pleasant Hill high—level	Gold Ridge l.f.s. over sandstone	'48 16-20-0, 5# per T '49 16-20-0, 5# per T	large	vigorous	large	M to L	8%
5	Cherry Ridge level on ridge	Gold Ridge f.s.l. over sandstone	'48 16-20-0, 400# per A plus some 10-10-5 '49 16-20, 250# per A	large (orchard shady)	vigorous	large	M to L	trace
6	Graton bench land	Gold Ridge f.s.l. over sandstone	'48 16-20-0, 3# per T '49 16-20-0, 3# per T	M to L	vigorous	moderate	L to VL	15%
7	Forestville north slope	Gold Ridge f.s.l. over sandstone	'47 am. nitrate, 500# per A 10-10-5, 300# per A '48 none '49 am. nitrate, 300# per A	M to L	vigorous	moderate	M to L	25%
8	Sebastopol east slope	Sebastopol gr.s.l. over clay	'47 & '48 8-8-5, 8# per T '49 am. sulphate, 5# per T	large	vigorous	heavy	M to L	8%
9	Spring Hill S.W. slope	Graton f.s.l. over sandstone	'48 poultry manure, 3-4 T per A 10-10-5, 500# per A '49 poultry manure, approx. 3-4 ton per A	medium	vigorous	moderate, approx. 10 bx. per tree	M to L	10%

\* s.l. = sandy loam; f.s.l. = fine sandy loam; gr.s.l. = gravelly sandy loam; l.f.s. = loamy fine sand.

† Figures represent approximate average amounts of striping on surface of samples.

Sebastopol, west to Graton and north to Forestville. A tabulation of the orchards, together with a description of the trees, soil types and fertilizer practices is shown in table 1.

**Time of harvest.** Four experimental pickings were made from a selected group of trees in each orchard. To determine the influence of time of harvest on storage quality, the first picking was made on July 26, the approximate date on which most orchardists either began their harvest or considered the apples sufficiently mature for picking.\* Subsequent pickings occurred on August 2, 9, and 17. On August 17 little—and in one instance—no fruit remained on the trees. For this reason, some of the storage samples collected were more variable in character than those secured earlier. They did, however, represent reasonably well the fruit at the end of the picking season.

**Selection for size.** At each picking, the apples from each orchard were sorted into 3 groups: small (  $2\frac{1}{2}$  inches diameter), medium (  $2\frac{7}{8}$  inches diameter), and large (  $3\frac{1}{4}$  inches in diameter).

**Other factors.** Extra lots of especially well-striped fruit were selected from several orchards for comparison

with average colored specimens. All lots of fruit were placed in cold storage within 4 hours of harvest, except duplicate lots of medium sized fruit that were purposely exposed to outside temperatures for 3 days.

The fruit was stored loose in field lugs, in the plant of D. Barlow and Sons, Sebastopol, where it was held for most of the time at a temperature of 32° F, and at a relative humidity of 80–85 per cent.

To check the influence of artificial atmospheres in extending the storage life of Gravenstein apples beyond that of a normal atmosphere of 21 per cent oxygen and 79 per cent nitrogen, small lots of medium sized apples from a single orchard were taken to Davis and stored in atmospheres containing only  $2\frac{1}{2}$  to 5 per cent oxygen and 5 to 10 per cent carbon dioxide. Normal air was used as a check.

Only laboratory methods were used in this test. The apples (about 100 specimens) were placed in wide-mouthed 5-gallon glass jars, fitted with metal tops which permitted a continuous flow of the various atmospheres in and out of the jars. The gases comprising the atmospheres were secured from pressure tanks.

### ***These points were checked . . .***

**Before and during storage, several factors were checked and the results recorded.**

**Color development** in the fruit was ascertained by using the terms *dark green, light green, yellowish-green, green-*

*ish-yellow*, and *yellow* to describe the ground color of the fruit. The descriptive terms were given numerical values from 1 to 5, respectively.

**Red striping** on the fruit was estimated in percentages of surface covered. Estimating was done by eye.

**Firmness** of the fruit was determined by the use of a standard pressure tester.

**Soluble solids** were determined by the use of a hand refractometer.

**Disorders** such as bitter pit, scald, shriveling, and breakdown were noted by examination of the fruit at harvest time and after various intervals of storage.

\* Some growers over the district had started picking July 16 but only one co-operating grower had picked over the block of test trees from which experimental fruit was secured. One other co-operator, whose apples were considered satisfactory earlier, did not pick any fruit from the experimental group of trees until August 9.



**Shipping qualities** of the fruit were determined by removing certain lots of medium sized apples from storage after 7 to 8 weeks, transferring them to Davis and storing them at 42° F for a 10-day simulated shipping period. At the end of the shipping period the condition of the apples was checked in relation to sales appeal.

## **Variations noted in the selected factors during picking and before storing.**

**Color development.** The average over-all color change in all sizes of all 9 samples of apples increased from a light green color (value 2.25) on July 14, to between a greenish-yellow to yellow color (value 4.4) on August 17 (fig. 1A).

Color change prior to July 26 was not marked. Between July 26 and August 10, the color changed from between a light to yellowish-green to a greenish-yellow. (In 2 or 3 orchards the fruit was still predominantly green, and in 2 or 3 others, decidedly yellowish to yellow.)

After August 10 the ground color increased more slowly because in most orchards the more mature fruit had been harvested and typical samples were difficult to secure.

No separate color observations on different sizes of fruit were made prior to July 26, but on this date and subsequently average color development and increase was similar for fruit of different sizes.

**Red striping.** The percentage of the fruit surface showing red striping was first determined on July 26. At this time the amount of striping (according to best estimates) averaged 7 per cent. (Fig. 1A.) Fruit from 4 orchards showed 1 to 2 per cent and that from 2 others showed 15 and 17 per cent.

Two weeks later, on August 10, the

**Processing qualities** were determined by taking portions of the fruit from storage after about 8 weeks, and again after 3 and 4 months, and making them into applesauce. The sauce was then inspected and evaluated for quality.

**Dessert qualities** were checked by sampling at each inspection.

## ***These were the results . . .***

average had increased to 27 per cent with extremes of 5 and 60 per cent. On this same date, box lots of medium sized apples that were selected for maximum development of red color were harvested from 7 orchards. These colored samples averaged 70 per cent striping, but such fruit could only be found in 2 or 3 of the test orchards.

At the last experimental picking, on August 17, all the more highly colored apples had been removed from the trees, so the average percentage of red color in the test apples declined.

As with ground color, size of fruit did not appear to influence development of red striping. Striping was determined largely, if not entirely by the exposure of the individual apples to sunlight, vigor of the trees, density of foliage and position of the fruit on the branches.

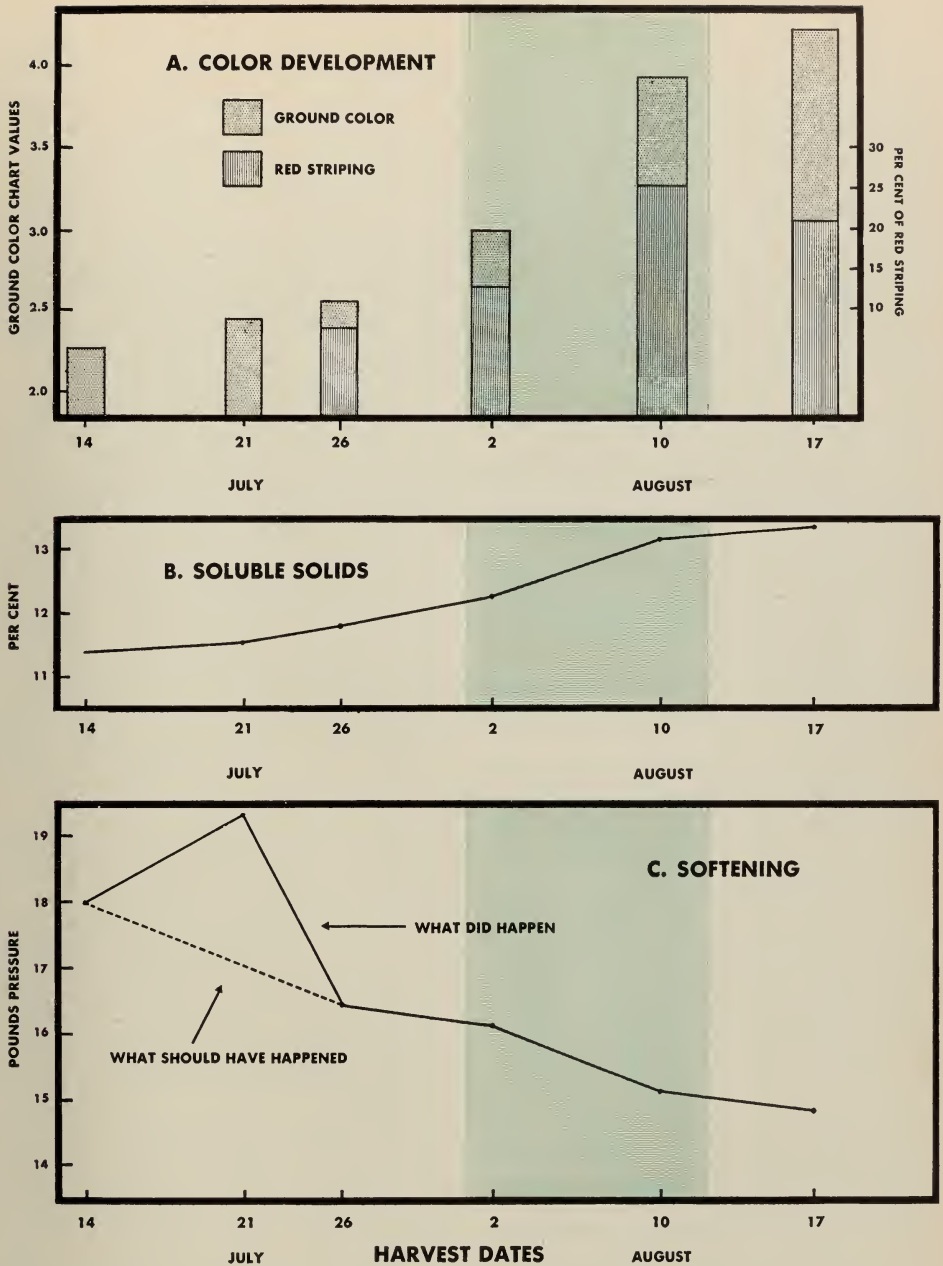
**Soluble solids.** The average percentage of soluble solids in fruit of all sizes from all orchards was 11.3 per cent on July 14, and 13.4 per cent on August 17. (Fig. 1B.) The increase paralleled the increase in ground color and the parallel was even more noticeable with the increase in development of red striping.

The soluble solids level of 11.5 per cent was reached on July 21 and increased steadily with maturity. As with color development, the normal rate of increase of soluble solids was low at the last experimental picking, and for the same reason.

Size of the fruit at the different pickings appeared to have no influence on the amount of soluble solids present.



Fig. 1. Ripening Changes During Harvest.



The shaded area shows the period during which fruit for storing should have been harvested in 1949. Medium sized apples picked during this period stood up better in subsequent storage tests—showed less development of bitter pit and scald, only a normal amount of breakdown, even when subjected to a delay between harvesting and storing.

Table 2. Soluble Solids in Gravensteins When Harvested and After 120 Days in Storage.

	1st pick.	2d pick.	3d pick.	4th pick.
After 120 days in storage . . . . .	12.9	13.4	14.2	14.2
When harvested . . . . .	11.7	12.3	13.0	13.3
Gain . . . . .	1.2	1.2	1.2	0.9
Percentage gain . . . . .	10.0	9.0	8.4	6.3

**Firmness.** The average pressure tests of all sizes of apples, made on July 21 were for some unexplained reason approximately 1 pound firmer than those taken a week earlier. Also, the firmness on August 17 was too high. (See fig. 1C.) From the graph, however, it will be seen that from mid-July to mid-August average softening was approximately 3½ pounds—from 18 down to 14.5 pounds.\* Variation in softening ranged from less than 2 pounds to nearly 5 pounds.

At each harvest date, large apples averaged 1.8 to 2.5 pounds softer than small apples, with medium sized fruit intermediate.

One sample of very large apples picked August 17, was 1 pound softer than large (3¼-inch) fruit, and 2.4 pounds softer than medium sized fruit.

At the third picking, August 2, the firmness of 6 samples of medium sized, highly colored fruit (50 to 80 per cent red striped), was 1.7 pounds greater than that of average color, medium size, from the same orchard and trees.

### **During storage, changes begun on the tree, continued to take place in:**

**Ground color.** Due to the fact that the color chart used by the Bureau of

\* This represents softening under orchard conditions where from time to time part of the crop is removed by picking. Had only test samples been removed, the rate and amount of softening would probably have been greater.

Fruit and Vegetable Standardization gave only 3 shades of green, ground color changes beyond a yellowish-green (No. 3) were only approximated.

Apples stored the same day as harvested showed no change in ground color for the first 2 months in storage, and only gradual changes during the remainder of the time. Fruit from several orchards where the apples were of a rather intense green when harvested, changed little in 120 days, but most other lots increased from a yellowish-green (No. 3) to a greenish-yellow (No. 4)—or if they were approaching a greenish-yellow when stored, changed to a light or full yellow.

The amount of red striping on the apples did not change after harvest, but became more noticeable, brighter, and of greater intensity as the ground color changed from green toward yellow.

The ground color changes in some lots were not uniform, particularly in small sized fruit where some of the apples remained green and others became light yellow. This variability was not noted until relatively late in the storage period.

The 3-day delay in storing certain samples resulted in noticeable color changes after only 6 weeks of storage. These changes became more marked, compared with apples stored immediately, the longer the fruit was stored.

**Soluble solids** which increased in the fruit prior to and during the harvest period, continued to increase, but at a much slower rate, in storage.

Table 2 shows soluble solids changes at harvest time and during storage.

**Firmness.** Lack of sufficient fruit made it impossible to get accurate determinations of softening in storage at frequent intervals because pressure test readings could be made only on sound fruit. Since there were relatively few sound apples at the last reading those tested probably resulted in an average about 1 pound too high.

With allowances made for these errors, general softening during 120 days in storage was 4 to 5 pounds. (Fig. 2, page 12.) Apples at the third and fourth pickings were approximately 1 pound softer than those of the first and second pickings when harvested, and subsequently softened a little more.

Softening precedes breakdown, and breakdown (as described later) was definitely correlated with time of harvest.

The amount of softening in the different sizes of fruit was essentially the same.

**Flavor.** Deterioration in flavor was tested only objectively by comparative tasting. It is difficult of measurement but late in the storage period is associated with flesh softening.

## **And these disorders developed in varying degrees of severity:**

**Bitter Pit Development.** Gravensteins are inherently susceptible to bitter pit (brown, corky spots in the flesh). While this physiological trouble has its inception in the orchard, it is considered to be a storage disorder because relatively little of it develops before the fruit is picked. Bitter pit is associated with early-harvested fruit, and was more severe in certain orchards than in others.

**In Relation to Harvest Dates.** After 6 weeks in storage, the average amount of bitter pit was 4.9 per cent; classified as being slight or moderate in severity. During the next 2 weeks, or after 60 days,

the percentage more than doubled, reaching 10.6 per cent. It also increased in severity.

Pitting in apples harvested August 2 and 10 was less, after 120 days, than it was in the first picking after 60 days. Pitting in the apples harvested August 17 amounted to only 4.0 per cent.

Just how much bitter pit would have developed in apples from the first picking in 120 days can only be estimated because a portion of the most severely pitted fruit was removed from storage after 2 months. It is believed, however, that it would have been between 25 and 30 per cent.

The over-all picture of bitter pit development of fruit picked on different dates is shown in fig. 3A, page 13.

**In Relation to Soluble Solids.** With bitter pit decreasing and soluble solids increasing as the harvest season advances, it might be expected that differences in the soluble solids level of the fruit would be some indication of its susceptibility to bitter pit. No differences in this respect were found.

To attempt a definite correlation it would probably be necessary to test individual apples which did and did not show pitting, rather than to make an average test of the two lots. Even in this case, however, the results would be similar. Bitter pit in the flesh is confined to small areas from which it would be difficult to extract any juice for testing. Thus, in a fruit with severe bitter pit, the juice obtained for the soluble solid test would come largely, if not entirely from the normal tissues.

**In Relation to Orchards.** The amount of bitter pit in the apples from different orchards varied greatly. Fig. 3B illustrates the development in fruit harvested July 26, and the variation between the 2 high and 3 low orchards. In a period of 14 days, the amount of bitter pit in apples from the high orchards jumped from 9 to 20 per cent; in the low orchards, pitting increased from 1 or 2 per cent to 2.6. Since the average amount

Fig. 2. Softening in Storage.

A.—Different Pickings—Sizes Averaged.

B.—Fruit Harvested August 10—Softening by Sizes.

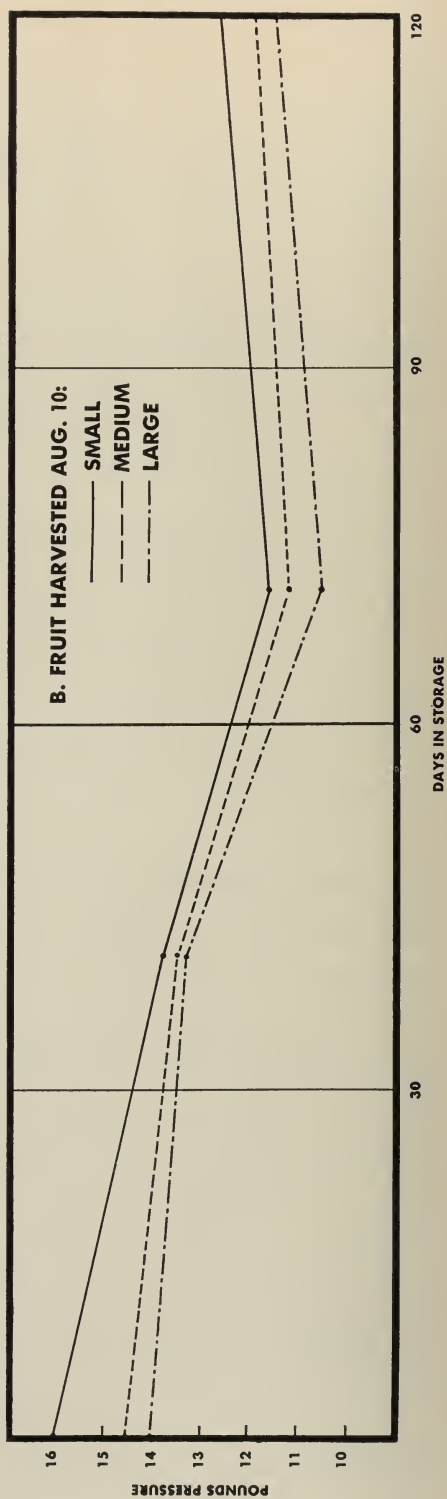
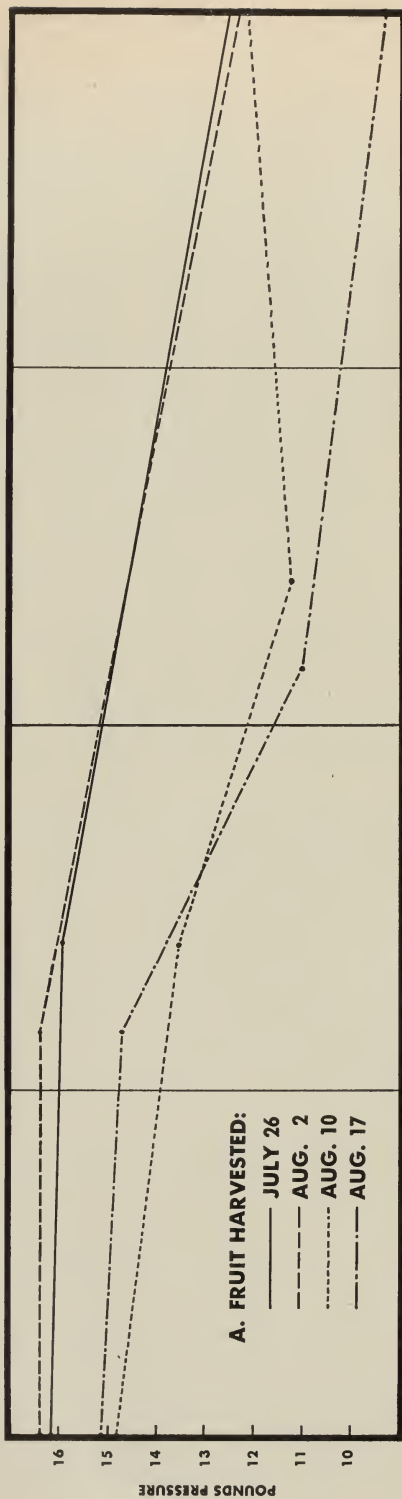
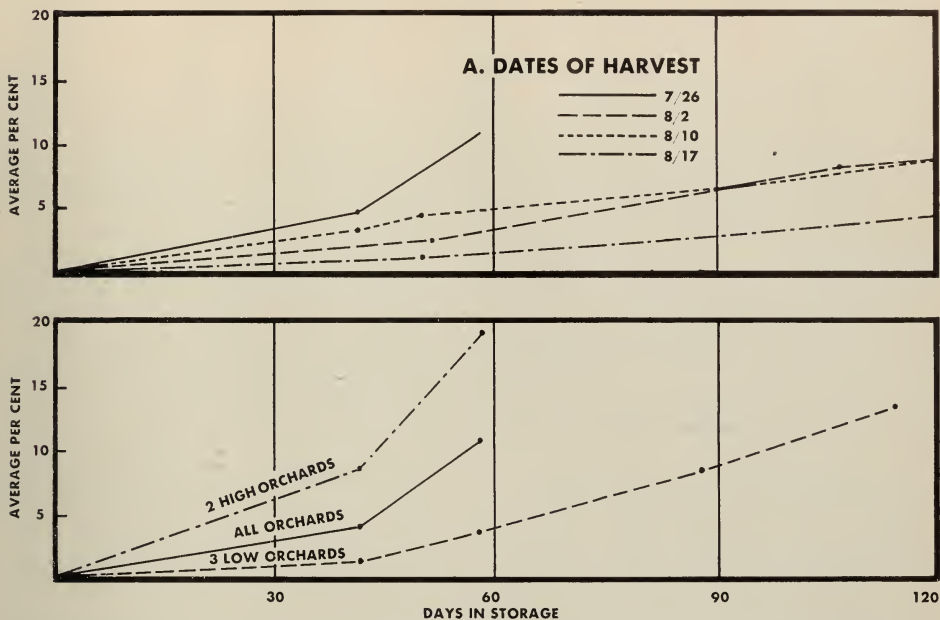




Fig. 3. Bitter Pit Development—Large, Medium and Small Sizes Averaged.

A.—Comparison, Different Pickings—All Orchards\*.

B.—Comparison, All Orchards with 2 High and 3 Low Orchards—1st Picking July 26, 1949.



\* The fact that for a time, about 1 per cent more bitter pit developed in the 3rd picking than in the 2nd, is not significant. No real difference existed between these pickings.

of bitter pit in the fruit from 4 of the 9 orchards was up to 17 per cent, it was removed from storage and used for processing. (See page 20.)

Variations in the later pickings were also noted but became less marked as the season advanced. As shown, the total amount of bitter pit in the fruit harvested August 17 was, for 2 months at least, negligible.

While the apples from different orchards showed a wide variation in their susceptibility to pitting, it is impossible from a 1 year's storage test to make a definite correlation between orchard practices and bitter pit development. In orchards of vigorous growing trees where foliage screens out most of the sunlight, the fruit is usually of greener color, often softer and larger than fruit from less vigorous trees. From the standpoint of bitter pit development, such fruit is looked upon with suspicion. For some

reason however, fruit from 2 such orchards failed to develop as much pitting as did fruit from some others where the trees had received no fertilizer for 5 years or more, and were only moderately vigorous.

The problem of the relationship of orchard practices to keeping quality is one for more critical study.

**In Relation to Red Striping.** No direct comparisons were made between striped and unstriped apples harvested July 26 and August 2. Comparisons were made, however, between medium sized fruit harvested in 6 of the 9 orchards on August 10.

Although the ground color of the fruit did not show any close correlation with bitter pit development, there did appear to be a rather definite inverse correlation between striping and pitting, even after mid-season. Well striped apples—those produced on trees open to sunlight—

Table 3. Percentage of Bitter Pit in Relation to Red Striping—  
Medium Sized Fruit—Harvested August 10.

Amount of red striping	Storage period			
	30 days	60 days	90 days	120 days
Little or none.....	2.4	4.2	5.4	7.8
$\frac{2}{3}$ of surface.....	0.4	1.3	2.2	2.3

showed less pitting than those which had less striping. The difference was very marked in one orchard where bitter pit was most severe. Fruit unselected for striping developed 18 per cent of pitting, in 6 weeks, compared with 1 per cent in well striped fruit. Differences in the other 5 orchards, due to a low percentage of bitter pit in all of them, were not great. The average differences for all 6 orchards are shown in table 3.

**In Relation to Size of Fruit.** The results of the experiments confirmed previous tests and general experience—that large apples are most susceptible to bitter pit. Figures 4 and 5 illustrate the results obtained.

More pitting developed on fruit 3 inches or more in diameter, at each of

the 4 pickings. All sizes of late-picked apples, however, were practically free of bitter pit after 90 days in storage.

Differences in pitting between medium and small sized apples were small and not consistent. In the first 2 pickings, the small fruit developed 2 to 3 per cent more pitting than medium sized apples. In the third, and also the fourth, after the fruit was stored 90 days, the reverse was true.

**In Relation to Temperatures.** Delay in placing the apples in cold storage did not increase bitter pit. In fact, the relatively few comparisons made seemed to substantiate an earlier test\* which in-

\* Allen, F. W. Maturity and rate of ripening of Gravenstein apples in relation to bitter pit development. Proc. Amer. Soc. Hort. Sci. 639-645, 1931.

Fig. 4. Bitter Pit Development—Maturity and Sizes—All Orchards.

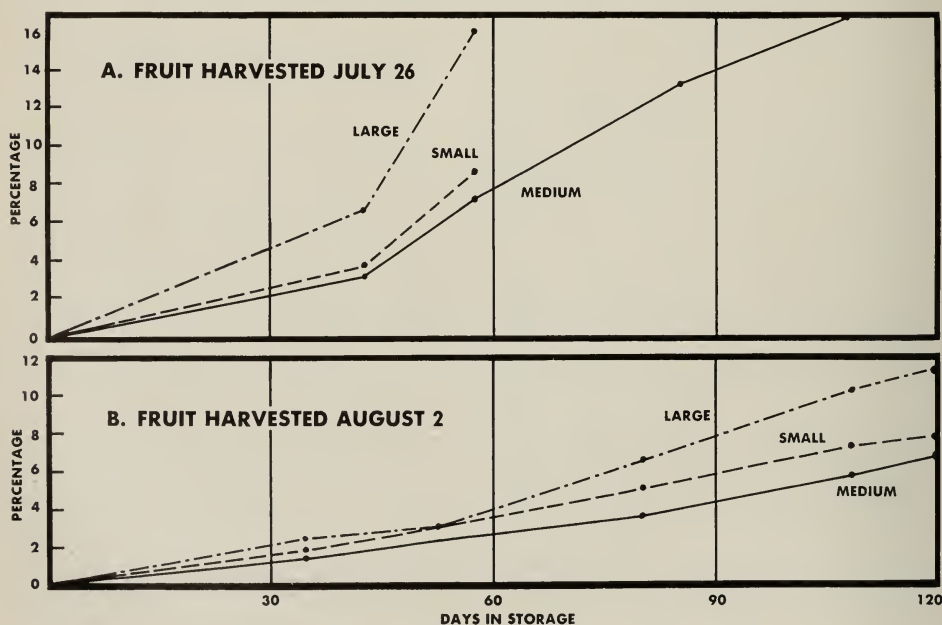
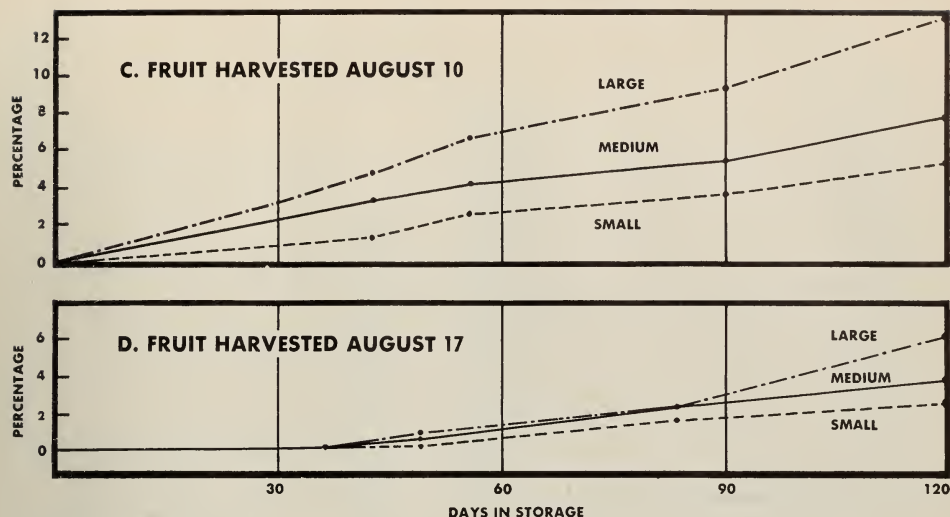


Fig. 5. Bitter Pit Development—Maturity and Sizes—All Orchards.



indicated that the more rapidly fruit is ripened, the less bitter pit development.

Low storage temperatures were found to retard bitter pit, but when stored fruit was removed from storage and placed in a higher temperature to ripen, it developed more bitter pit than fruit held at a higher temperature until ripe.

Harvested apples ripen more rapidly at ordinary temperatures than those left on trees. Therefore several days delay in storing of apples susceptible to bitter pit might, in this regard, prove advantageous. However, fruit that was subjected to a delay between harvesting and storing ripened more rapidly and was therefore more subject to subsequent breakdown.

**Scald Development.** Scald on Gravensteins is a much less serious storage trouble than bitter pit. Its initial appearance is usually later in the storage period and, except in the advanced stages, is only "skin deep." Even though it spoils the appearance for sale on the fresh market, apples showing scald may still be acceptable for processing.

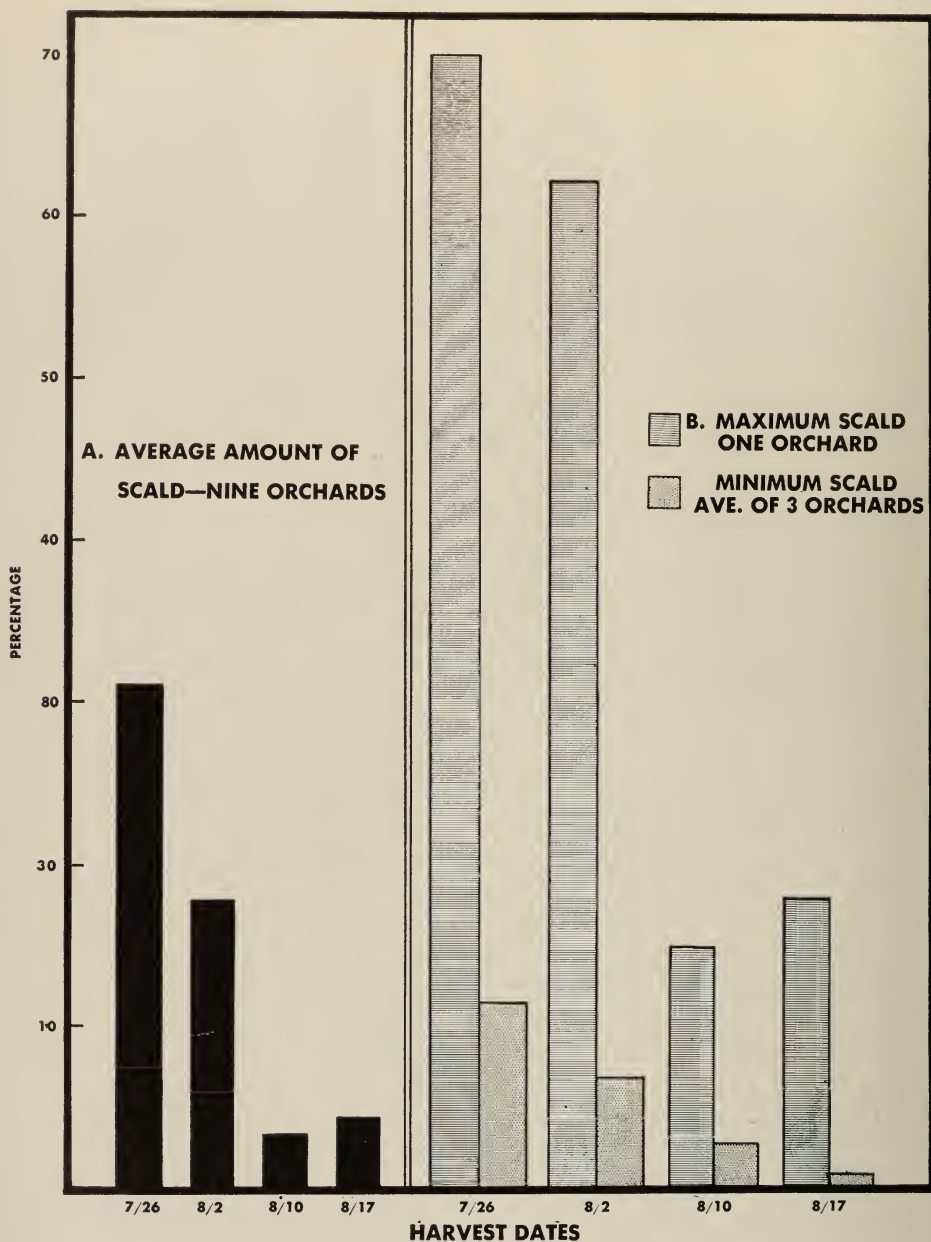
Incipient scald was first noticed on some lots of fruit after 90 days in storage. During the next 30 days it increased rapidly, both in percentage and in severity.

**In Relation to Harvest Dates.** Scald is usually worse on early-picked fruit. After 120 days' storage, the average amount of scald on fruit harvested July 26 was nearly twice that in the pickings made August 2. (Fig. 6.) In contrast with 30 per cent in the first picking and 18 per cent in the second, less than 5 per cent developed in fruit harvested August 10 and 17. Early picking is, therefore, undesirable because of scald and also bitter pit development.

**In Relation to Orchards.** Fruit from different orchards varied as widely in susceptibility to scald as to bitter pit. After 120 days, fruit from one orchard developed 70 per cent scald on that picked July 26, and 60 per cent on that picked August 2. (Fig. 6.) The average development in fruit harvested on the same dates from 3 other orchards was only 11 and 17 per cent respectively.\* The amount of scald on the fruit picked August 10 and 17 was so much less than that on the earlier pickings that the slight increase between the last 2 pickings is not considered significant.

\* In 1931, Gravensteins were harvested July 7 from 6 orchards in the Sebastopol and Geyserville districts. After 15 weeks of storage the percentages of scald which had developed in the different lots varied from 45 to 80 per cent.

Fig. 6. Scald—Comparison of Harvest Dates and Orchard Variability—Medium Sized Fruit Stored 120 Days at 32°F.





**In Relation to Fruit Color.** Scald development could not always be correlated with ground color, but on the average it was less on fruit with considerable red striping.

**In Relation to Fruit Size.** Size of the fruit had no apparent relation to the development of scald as it developed in these experiments.

**In Relation to Handling Practices.** Results of the 1949 experiments failed to substantiate observations made on previous tests, that a delay of several days between harvesting and storage results in a greater percentage of scald.

**Development of Breakdown** (a physiological decay) results in softening and browning of the flesh. It usually occurs in fruit which is: overmature when harvested; has been allowed to ripen too much before or during storage; held beyond its commercial storage life. In addition, premature breakdown may show in fruit from certain orchards, for reasons that are not always explainable.

In general, breakdown is looked upon as a trouble of "old age"—it often follows or is associated with loss of flavor and with scald.

In the experimental lots of Gravensteins stored the same day as harvested, a maximum of 3 per cent of breakdown occurred in fruit from one orchard during the first 3 months in storage. During the next 30 days, fruit from 3 other orchards was still free from breakdown, while that in the first orchard had increased to 17 per cent. A much greater percentage developed in fruit that was subjected to a delay between harvesting and storage.

**In Relation to Harvest Dates.** The relationship of breakdown to harvest dates is of little consequence until the fruit has been stored from 75 to 90 days. When stored longer than 90 days, breakdown becomes more serious in later-picked fruit.

After 120 days of storage, the average

of breakdown in all sizes of fruit was as follows:

Date harvested	Percentage of breakdown
July 26 .....	1.5
Aug. 2 .....	2.3
Aug. 10 .....	5.3
Aug. 17 .....	5.9

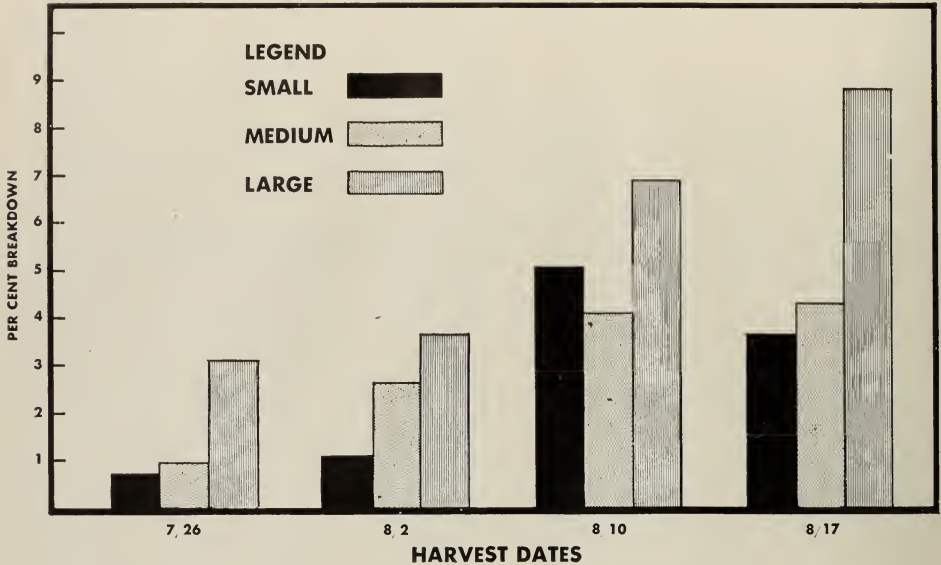
**In Relation to Orchards.** The percentages of breakdown in fruit from different orchards were quite variable. Fruit harvested August 10 and 17, from 3 orchards, developed only 0.3 to 3.0 per cent breakdown in 120 days. In fruit from 2 other orchards, there was 22 and 30 per cent. Both of the latter orchards had been rather heavily fertilized, and much of the excessive breakdown was in large fruit. Similar conditions, however, seemed to be present in other orchards and in other large fruit which showed much less of the trouble. Medium sized apples from one orchard developed no breakdown in 120 days, even with delayed storage.

**In Relation to Fruit Size.** While the over-all averages, as shown above do not seem excessive, figure 7 shows the results more graphically according to fruit sizes in the different pickings. With the exception of fruit from one orchard, picked August 10, where breakdown was serious in all sizes, large apples developed approximately 3 times as much breakdown as small ones. The amount showing in the last picking was nearly 10 per cent—all of this fruit was worthless.

**In Relation to Storage Delay.** Comparisons of breakdown in immediate and delayed storage apples were made only with medium sized fruit.

After 4 months in storage, breakdown in fruit harvested July 26, and stored the day it was picked, averaged 0.9 per cent: breakdown in the apples subjected to 3 days' delay in storage averaged 1.7 per cent. At this time, a delay of several days in storage appeared to be of little consequence.

Fig. 7. Breakdown—Comparison Amounts in Relation to Size and Time of Harvest—Fruit Stored for 120 Days.



Breakdown in fruit of subsequent pickings became progressively worse, and the influence of delayed storage on these pickings is shown in fig. 8. The variations, as well as the averages are shown.

After storage for 120 days, delayed-stored apples picked as late as August 17 averaged nearly 25 per cent breakdown—fruit from one orchard being as high as 70 per cent. From one-half to two-thirds of this breakdown occurred 30 days earlier.

### Tests gave data on shipping possibilities.

Between October 5 and 15, after 7 to 8 weeks in storage, samples of medium sized apples from the second, third and fourth pickings were removed from storage and held for a shipping period at 42° F. Upon “arrival” each lot was observed for appearance, condition and flavor.

**Appearance** of the different immediately stored lots of fruit changed but little

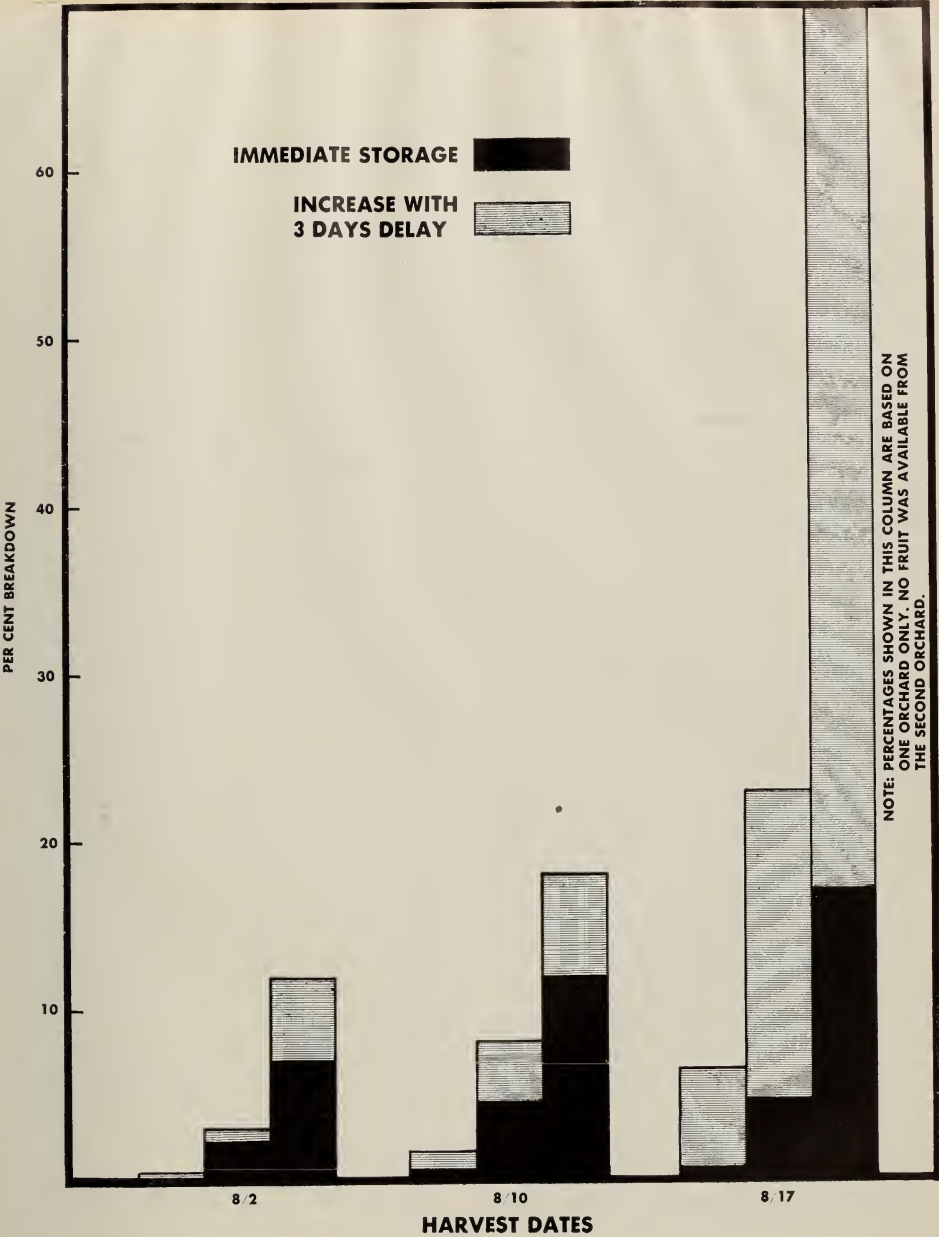
during the transit period—ground color in most lots increased slightly. In delayed storage lots, increased yellow was apparent; this was also evident when the samples were removed from storage. Development of an overripe yellow color in some fruits of certain lots, especially those of the second picking, detracted from their appearance.

**Softening** took place to a somewhat greater degree in fruit harvested at the second picking, averaging 3½ to 4 pounds. Fruit from the third and fourth pickings softened somewhat less during the period of the simulated shipping tests.

**Bitter pit** developed little during the transit period. After 8 weeks’ storage period most lots of fruit were still either free from bitter pit, or else showed less than 5 per cent slight pitting. In one lot, however, 25 per cent bitter pit was present when the sample was removed from storage. (Fruit of the first picking which ran much higher in percentage of bitter pit was not included in the shipping test.)

**Flavor** of the fruit of the third and fourth pickings was somewhat less acid

Fig. 8. Breakdown—Comparison in Immediate and Delayed Storage Lots; Also Relative Percentages in 3 Low, All, and 2 High Orchards on 3 Picking Dates. Medium Sized Fruit Stored 120 Days.





than that of the second. With the possible exception of delayed storage samples, and fruit of high color of the later pickings, all of the apples needed a number of days at 65°–75° F to attain good flavor after shipping.

**Delayed storage** resulted, in some instances, in the apples arriving in a mel-low, rather than a firm, crisp, juicy condition. These, particularly in the fourth picking, would have been considered "overripe" by eastern receivers.

**The general condition** of various lots varied markedly between growers. Disregarding the specimens of bitter pit (which could be sorted out before packing) the appearance of the fruit ranged from the green, soft apples, sometimes showing slight shriveling, to the more firm, striped fruit.

**Conclusions.** Because of the limited quantity of fruit held, the results of the simulated shipping tests are only indicative of what might be expected from the shipment of fruit previously held in storage. Where the fruit held well during the 2 months' storage period, it was generally in a good marketable condition after the shipping period.

It would appear almost self-evident that immature, or otherwise green colored fruit, without red striping, and also fruit of large size, should not be stored for future shipment. Even though some lots of such fruit may not develop serious bitter pit, the apples are likely to change color without uniformity, assume only a pale color at best, be more subject to shriveling, be of low dessert quality, and (if held too long) show serious scald. Such fruit can hardly be expected to compete in price on the eastern markets with the red fall varieties which would be found in mid-October.

On the other hand, firm, medium sized apples with good yellow color, plus red striping, were sound and attractive after 3 to 4 months and (if desired) could be shipped as fresh fruit after 60 to 75 days

in storage. In all instances, however, it should be recognized that the dessert quality of summer apples deteriorates in storage more rapidly than does that of the winter varieties. Perhaps, therefore, Gravensteins scheduled for eastern shipment should not be held longer than 4 to 6 weeks. Midseason pickings are more preferable than earlier or later ones.

### **Stored apples may be used to extend the processing season.**

Sample lots (5–15 boxes) of apples were taken from storage at intervals during a 135-day period, and sent to two local canneries to be made into applesauce.

In order to secure necessary storage data, all apples in these lots were handled a number of times previous to canning, and many of them showed some bruising. Some of the early-picked fruit had developed bitter pit—20 per cent of the apples in one lot. Some apples stored more than 3 months had developed scald.

Several months after processing, sauce made from the different lots, harvested on different dates and stored for different periods was scored by Doctor M. A. Joslyn, of the Division of Food Technology, and by a committee representing all of the canneries in the Sebastopol area, and also by others.

The scoring of Doctor Joslyn and of the committee, based on the United States Department of Agriculture standard for canned applesauce is given in table 4, on next page.

It was the opinion of Doctor Joslyn, who was somewhat more critical in his scoring than most of the committee, that the stored apples made a very acceptable product, even though it did not have the full Gravenstein flavor of sauce made from fresh apples, and lacked the color



Table 4. Test Scores of Gravenstein Applesauce.

Picking date	No. weeks apples stored	Score	
		Cannery committee	Doctor Joslyn
July 26 .....	9	90.5	86.0
July 26 .....	9*	90.7	89.0
July 26 .....	16	90.7	84.0
August 2 .....	8	89.1	88.0
August 2 .....	15	87.5	84.0
August 2 .....	19.5	86.7	80.0
August 10 .....	8	91.5	87.0
August 10 .....	14	90.4	87.0
August 10 .....	18	89.9	90.0
August 17 .....	7	89.9	88.0
August 17 .....	13	89.7	78.0
August 17 .....	17	88.4	81.0

\* This lot of fruit showed bitter pit in 20% of the apples.

and consistency necessary to make U. S. Fancy grade—a minimum score of 90.

The cannery committee considered the product to be at least of a strong U.S. Standard grade—the quality of most applesauce processed in the area.

It will be noted that in most instances sauce made from apples stored for 4 months or longer was usually given a lower score than that from apples held for a shorter period of time.

In connection with the scores it should be pointed out that the apples probably received more bruising than would normally occur in good commercial handling, and that the canning was done under several handicaps. The processing was done at a time when late varieties were also being processed and it was difficult to make adjustments in cooking time, sugar and moisture for such small lots of Gravensteins. In the opinion of

the processors this resulted in a lower score in consistency and color of the sauce than would be normal under a full run of fruit.

Bitter pit, which is the main storage defect during the first 3 months of storage, does not destroy the apples for canning, unless it is severe and deepseated. Such fruit would require considerable trimming.

Scald, unless very severe, affects the skin only, and does not injure the fruit for canning. Loss of flavor, caused by long storage will tend to lower the flavor of the applesauce.

Breakdown, which may develop on the more mature fruit after 3 months in storage, is a defect which would have to be culled out before canning. Any lots showing a considerable percentage of breakdown would have to be discounted in price.

### ***These recommendations can be made . . .***

#### **Cold storage is advisable but has limitations in . . .**

**Storing for Fresh Markets.** In the California markets, buyers of fresh fruits

(particularly consumers) make their purchases largely on the basis of appearance, so the apples should be attractive as well as good.

These requirements demand that the apples be removed from storage and placed on sale before storage troubles

make their appearance. If this is not done, all specimens showing any type of storage trouble should be sorted out. In either case, fruit offered for sale should still be firm, bright, sound, and of good appearance. It must still have sufficient storage life to remain in marketable condition for the time it will be exposed to higher air temperatures—possibly 2 weeks.

For this reason, as well as economic ones, commercial storage of Gravenstein apples for fresh fruit sale should end *before* any considerable percentage of specimens show shriveling, bitter pit, scald, or breakdown.

On the eastern market, wholesale receivers are critical of any fruit showing much ripening and fruit which might meet ready sale in California markets would probably be called “overripe” on eastern markets.

Where a portion of the stored crop may be selected out, packed and shipped to eastern markets, the storage period should be from one-half to two-thirds that of fruit for local markets. If the apples are packed prior to storage, and then shipped with minimum exposure to normal air temperature in loading, compara-

tively little ripening will occur in transit. Some lots of such fruit, however, may after only several weeks, show enough bitter pit to make them unattractive on arrival.

Where the fruit is stored loose, sorted and packed just prior to shipment, then its temperature is raised and in some lots noticeable ripening and bitter pit may occur in transit.

**Storing Fruit for Processing.** Gravensteins to be used for applesauce may be held in storage nearer to the end of their life than when sold as fresh fruit. Quality of the finished product is the limiting factor, rather than appearance of the fruit. Incipient scald and bitter pit will not make any appreciable difference in the quality of the sauce. Loss of fresh fruit flavor will adversely affect the quality of the canned product and browning and breakdown render the fruit valueless. Fruit showing these disorders should be removed from storage before the condition becomes serious.

Table 5 shows the spread in storage life of fruit destined for different purposes. The periods of time shown exclude, for the most part, storage of any early-picked fruit, and assume not more

Table 5. Commercial Storage Life of Gravensteins, 1949. Fruit Harvested Mid-season—Stored Immediately at 32° F.

Market	Keeping quality of apples			Limiting factors
	Best to good		Poor	
	Maximum days	Av. days	Max.—Min.	
FRESH FRUIT				
Eastern	75	50–30	15–0	Bitter pit—lack of attractive appearance and of red striping.
California	110	85–60	30–20	Bitter pit followed by scald after 90 days. Poor color. Deterioration in texture and flavor.
PROCESSING	135	110–85	60–45	Quality of finished product—influenced by amount of bitter pit, breakdown and loss of flavor.

than 12-15 hours of time elapsing between harvesting and storage. The range of days shown is intended to allow for variability in the keeping qualities of fruits from different orchards, types and sizes of fruit.

These recommended storage periods are based on the results of only one season, and may need to be modified in the light of additional experience.

## **Artificial atmosphere helped in some ways... detracted in others.**

The results of holding Gravenstein apples in artificial atmospheres are only indicative of what might be expected in a commercial storage plant, where the carbon dioxide in the normal atmosphere would be built up, and the oxygen reduced by respiration of the fruit. However, as found from previous experiments with Yellow Newtown apples and Bartlett pears, softening and color changes in Gravensteins may be materially reduced by storing them in atmospheres containing 5 to 10 per cent carbon dioxide ( $\text{CO}_2$ ) and a similar or less percentage of oxygen ( $\text{O}_2$ ).

**At 32° F**, apples held for 120 days in an artificial atmosphere of 5 per cent  $\text{CO}_2$ -2½ per cent  $\text{O}_2$  were definitely of greener color (almost no color change) and firmer (13.3 pounds pressure) than those held in normal air. The general appearance was good, although some slight scald had appeared.

To the taste, the apples were definitely less ripe—more tart—than the lot held in normal air.

After 180 days the fruit, with the exception of 30 per cent slight scald, was still firm, green, and of good appearance. However, some slight discoloration and incipient breakdown of the flesh was beginning to be apparent, and only a mild acid flavor remained.

A second lot of fruit, held in 10 per cent  $\text{CO}_2$ -10 per cent  $\text{O}_2$  was injured early in the life of the experiment, and no results of value were obtained.

**At 42° F**, apples held in normal air were yellow and ripe after 6 weeks and 30 per cent were decayed two weeks later. Fruit held in the carbon dioxide atmospheres showed only slight color changes. In fact the fruit held in an atmosphere of 5 per cent  $\text{CO}_2$ -2½ per cent  $\text{O}_2$  showed almost no color change during the entire holding period of 120 days.

All fruit stored in the artificial atmospheres was in good marketable condition—but a little lacking in flavor—after 8 weeks. After 90 days, from one-third to one-half of the specimens were showing slight to moderate scald. Possibly the fruit would still have been acceptable for processing, but the general dessert quality had deteriorated.

These preliminary trials in holding Gravensteins in artificial atmospheres both at 32° and 42° F, indicate something of the extent to which coloring, softening and decay may be retarded. The flavor, or dessert quality of the fruit, however, is not as good as that stored in normal air.

Air-stored fruit, as long as it remains sound, is sweeter and more aromatic. Difference in taste of the fruit is probably due to a greater retention of acid in the artificial atmospheres. No significant differences occurred in the percentage of soluble solids.

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